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COST-EFFECTIVE MITIGATION STRATEGY DEVELOPMENT FOR BUILDING RELATED EARTHQUAKE RISK

Annual Report 2018-2019

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Cover: Dust clouds of the Feb 2011 Christchurch earthquake (© Gillian Needham)

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EXECUTIVE SUMMARY

This annual report contains a summary of 12-month research undertaken by 4 partner institutions towards the development of cost-effective seismic retrofit methods for vulnerable Australian buildings.

Progress has been made in 3 complementary fronts to:

1) Understand the seismic vulnerabilities of existing unreinforced masonry (URM) and limited ductile reinforced concrete (LDRC) buildings and methods to address them through seismic retrofit;
2) Risk assessment of the building stock through development of an economic loss model; and
3) Advance an end user focused research utilization project in the area of community risk reduction. This is done through an Earthquake Mitigation Case Study for the historic town of York in Western Australia.

The first of the above components is being researched in the Universities of Adelaide, Melbourne, and Swinburne. This work includes investigation of existing building seismic capacities and development of retrofit techniques. The second area is being studied by Geoscience and the work includes estimating direct and indirect losses associated with building damage and benefits from seismic retrofit. The last component is being conducted utilizing the research findings in the two other areas in collaboration with the Western Australia Department of Fire and Emergency Services, York Shire Council and its residents.

Finally, using the new damage loss models and costings for seismically retrofitting buildings, recommendations are made for the development of seismic retrofit guidelines and policy based on the strong evidence base being developed by this CRC project team.

END-USER PROJECT IMPACT STATEMENT

Leesa Carson, *Geoscience Australia, Commonwealth*

During the past 12 months significant progress has been made towards one of the proposed End User project. As detailed under "Conference and workshop attendance", researchers from GA and Adelaide have been working towards the WA-based End User program.

Some of the engagement activities have included:

- Briefing at the Australian Earthquake Engineering Society (AEES) conference in November 2018 and an accompanying tour of York township to inspect key buildings involved in the study
- Submission of a joint abstract at the 2018 AFAC conference, with the End User delegates being the speakers
- Success in obtaining $250,000 grant from the National Disaster Resilience Program to facilitate implementation of the seismic strengthening solutions developed for York by a broader audience across the entire state of Western Australia. This will necessitate expanding the scope of building typologies (six for York) by three to adequately cover the wider range anticipated across the state.

INTRODUCTION

This project arose out of the on-going research efforts by the group involving structural engineering academics at the Universities of Adelaide, Melbourne and Swinburne with Geoscience Australia experts all working towards seismic risk reduction in Australia. Most of the research team are actively involved in the revision to the Australian Earthquake Loads standard (AS1170.4) as well as being members of the Australian Earthquake Engineering Society which is a Technical Society of Engineers Australia. The devastating impact of the 2010 – 11 earthquakes in the Christchurch region on the New Zealand economy and society has further motivated this group to contribute to this CRC's aims of risk reduction for all natural hazards in Australia.

This project addresses the need for an evidence base to inform decision making on the mitigation of the risk posed by the most vulnerable Australian buildings subject to earthquakes. While the focus of this project is on buildings, many of the project outputs will also be relevant for other Australian infrastructure such as bridges, roads and ports, while at the same time complementing other 'Natural Hazards' CRC project proposals for severe wind and flood.

Earthquake hazard has only been recognized in the design of Australian buildings since 1995. This failure has resulted in the presence of many buildings that represent a high risk to property, life and economic activity. These buildings also contribute to most of the post-disaster emergency management logistics and community recovery needs following major earthquakes. This vulnerability was in evidence in the Newcastle Earthquake of 1989, the Kalgoorlie Earthquake of 2010 and with similar building types in the Christchurch earthquake. With an overall building replacement rate of 2% nationally the legacy of vulnerable building persists in all cities and predominates in most business districts of lower growth regional centers.

The two most vulnerable building types that contribute disproportionately to community risk are unreinforced masonry and low ductility reinforced concrete frames. The damage to these will not only lead to direct repair costs but also to injuries and disruption to economic activity.

This research project will draw upon and extend existing research and capability within both academia and government to develop information that will inform policy, business and private individuals on their decisions concerning reducing vulnerability. It will also draw upon New Zealand initiatives that make use of local planning as an instrument for effecting mitigation.

WHAT THE PROJECT HAS BEEN UP TO

CONFERENCE AND WORKSHOP ATTENDANCE

BNH CRC RAF (June 2019) – Michael Griffith attended the Canberra RAF and gave an overview of the Earthquake Resilience Project's focus which has implications for economic modelling and development of public policy and legislation .

European Earthquake Engineering Conference (July 2018) – One paper was presented at the ECEE in Greece on the seismic risk associated with URM and LDRC buildings in the Melbourne CBD.

Australian Earthquake Engineering Conference (November 2018) – 5 papers including a Keynote were presented at the Australian Earthquake Engineering Society (AEES) conference, which was held in Perth. The presentations included a keynote presentation by Mark Edwards on the York Shire Council 'End User' project.

York End User Project Workshop (November 2018) – in parallel with the 2018 AEES conference in Perth, the York Project team met with the End Users and Department of Heritage WA staff to develop a proposal for additional funding through a NDRP grant to adapt the York project methodology for wider application across West Australia. Full details of this proposal (which was successful, announced in June 2019) are given in the 'Utilisation & Impact' section of this report.

13th North American Masonry Conference (June 2019) – One paper was presented on laboratory tests of clay brick masonry walls typical of heritage building types.

UNREINFORCED MASONRY BUILDINGS

In the past 12 months, research was undertaken to finalise the work on developing fragility curves for URM buildings that have been strengthened with a variety of seismic retrofit techniques and to a range of resistance levels in terms of the percentage of the current AS 1170.4 requirement for new buildings strength (NBS) such as 33%, 67% and 100% of NBS.

This work was furthered by investiagion into the costs associated with each retrofit technique in order to develop an economic loss model for use in estimating the cost-benefit ratios for various earthquake scenarios and retrofit strategies. This work is being trialled through the York Shire Council and WA DFES end-user project which is described in more detail in the following sections of this report.

LDRC BUILDINGS

In the past year, a comprehensive experimental testing program comprising of 14 column specimens, representative of typical Australian construction practice, was conducted to evaluate the collapse performance of limited ductile high-strength RC columns during earthquakes. The effect of a number of variables, including the level of the axial load supported by the column, and the type of

earthquake loading path was studied. The specimens were subjected to loading protocols, representative of actual earthquake loading on columns, developed by rigorous numerical analysis. An empirical model previously developed by the project team showed a very good correlation with the experimental results. The model, therefore, could be used by structural design engineers in Australia to reliably predict the non-linear response of RC columns. The results of the experimental testing have been presented in a couple of conference and journal papers.

A comprehensive review of the different strengthening and repair techniques for RC columns has also been conducted as part of the project. A review paper has been written in this regard, which provides useful insights to practitioners and designers for the selection of appropriate strengthening and repair techniques to meet the desired retrofitting objectives.

Studies have been undertaken to develop rapid vulnerability assessment of limited ductile reinforced concrete buildings. The method allows for Individual buildings to be assessed and ranked for their retrofitting priority. The assessment and retrofitting methodology involving a tiered process based on the presence of various vulnerable features of reinforced concrete buildings. The developed methodology is currently being tested on several case study buildings.

Studies have been conducted to develop a database of accelerograms that represent Australian conditions. The ground motion database will contain accelerograms representing earthquake events of varying intensity and site classes. The accelerograms are generated by 1) determining the appropriate ground motion models and dominating earthquake scenario; 2) developing conditional mean spectra for bedrock; 3) generating bedrock accelerograms based on the conditional mean spectra for bedrock; and 4) transferring bedrock accelerograms to soil site accelerograms.

ONGOING RESEARCH

Different options of retrofitting for limited ductile reinforced concrete buildings are currently being investigated to evaluate their relative impact on the seismic performance of RC buildings. The different retrofitting options have been applied to the RC building type that have been previously identified to be vulnerable in an earthquake. Studies are being undertaken to construct fragility curves of retrofitted limited ductile RC buildings.

UTILISATION AND IMPACT

OUTPUT TITLE - YORK EARTHQUAKE MITIGATION IMPLEMENTATION PROJECT

SUMMARY

Earthquake hazard was not fully recognized in Australian building design until the mid-1990s. This oversight has resulted in a legacy of vulnerable buildings in communities that can be damaged in moderate to severe Australian earthquakes. The 1968 Meckering earthquake illustrated this vulnerability by destroying the town of Meckering and causing significant damage to older unreinforced masonry (URM) buildings in neighboring towns, including York. Essentially all heritage buildings are URM and reliable information on the most effective retrofit measures for these and other high risk URM buildings is needed to inform strengthening programs, reduce risk and promote more resilient communities.

This project will examine the application of the outcomes of the Bushfire and Natural Hazards CRC (BNH CRC) York earthquake mitigation study to a number of York building types. The retrofit work will be separately managed through a linked parallel program funded through local and state government initiatives with the program using information developed under the current BNHCRC project for specific heritage retrofits. Retrofit information development for additional building types is included in this NDRP funded project to better cover the building range found in other WA communities and nationally. Finally, the project will communicate the availability and utility of the information through York community engagement, conferences and workshops for use in WA and nationally.

Output Description

The project outputs will be:

- Refinement and broadening of retrofit information with quantification of their effectiveness including three additional URM building typologies common in WA. This information will be made accessible online through the WA Department of Planning, Heritage and Lands website.

- Review of outcomes on the implementation of the retrofit measures on several building types with recommendations made on the learnings for broader implementation and the refinement of information. These recommendations will also cover learnings on strategies for the most effective provision of cost sharing funding to motivate property owners to invest in risk reduction.

- Engagement of building professional involved in the retrofit process to build knowledge and expertise in the cost-effective implementation of these strategies in York and more widely. This includes developing building industry skills within the communities to facilitate access to affordable construction skills to effect the works locally.

- Engagement with the local York community throughout the project raising risk awareness, understanding of the mitigation options, and improved uptake of retrofit cost-sharing to reduce the earthquake risk in York.

Utilisation Potential

- It is anticipated that the results of this work will have national application.

Utilisation Impact

- The potential impact is that communities can significantly reduce the impact that a moderate earthquake will have on them. Damage to URM buildings, in particular, will be reduced as well as minimizing all the associated intangible costs such as those due to building contents, business interruption, injuries, and fatalities.

Utilisation and Impact Evidence

- The proposal to support this work was funded by a $250,000 NDRP grant for three years: 2019-21. Work on this extension project will start in the second half of 2019.

PUBLICATIONS LIST (NOTE – ONLY PAPERS WITH CRC ACKNOWLEDGEMENT)

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PROJECT TEAM MEMBERS (CRC SUPPORT NOTED IN BRACKETS)

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- Yu Nie: Nonlinear finite element analysis of URM walls
- Chris Burton: Seismic retrofit of URM parapets

University of Melbourne:

- Bin Xing: Prioritisation strategy for seismic retrofitting of limited ductile reinforced concrete buildings in Australia
- Raneem Al Azeem: Seismic retrofit options for limited ductile RC buildings

Swinburne University:

- Scott Menegon: Seismic collapse behaviour of non-ductile RC walls
- Yassamin K Faiud Al-Ogaidi: FRP retrofit for non-ductile RC frames
- Alireza Zabihi: Seismic retrofit of RC beam-column joints
- Saim Raza: Collapse behavior of high-strength reinforced concrete columns in low to moderate seismic regions

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